IS 7204-4 (1980): Stabilized power supplies dc output, Part 4: Tests other than radio-frequency interference [ETD 31: Power Electronics]

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(Reaffirmed 2001)

Indian Standard

SPECIFICATION FOR STABILIZED POWER SUPPLIES, DC OUTPUT

PART IV TESTS OTHER THAN RADIO-FREQUENCY INTERFERENCE

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PART IV TESTS OTHER THAN RADIO-FREQUENCY INTERFERENCE

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Indian Standard

SPECIFICATION FOR STABILIZED POWER SUPPLIES, DC OUTPUT

PART IV TESTS OTHER THAN RADIO-FREQUENCY INTERFERENCE

0. FOREWORD

0.1 This Indian Standard (Part IV) was adopted by the Indian Standards Institution on 10 July 1980, after the draft finalized by the Power Converters Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard specification for stabilized power supplies, dc output, is being prepared in four parts. This part covers tests other than radio frequency interference. The other parts are as under:

Part I Terms and definitions

Part II Rating and performance

Part III Radio-frequency interference tests

0.3 This standard (Part IV) recommends procedures by which certain performance characteristics associated with voltage stabilized or current stabilized power supplies may be measured. The methods outlined are not the only way of conducting each measurement, but represent a reliable means of obtaining data against which other test procedures may be judged. An attempt has been made to minimize the need for specialized equipment, and no specific instruments are recommended.

0.4 In preparing this standard, assistance has been derived from IEC Pub : 478-4 (1976) ' Stabilized power supplies, dc output, Part 4 : Tests other than radio frequency interference', issued by the International Electrotechnical Commission.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard (Part IV) covers recommended procedures for measuring certain performance characteristics associated with stabilized power supplies designed to supply dc power supply from ac or dc source for applications such as computers, communication, laboratories and industry.

1.2 Calibrated stabilized power supplies for electrical measurement purposes are excluded.

2. GENERAL PRINCIPLES

2.1 General — The performance characteristics of stabilized power supplies are determined in terms of the effect a varying influence quantity has upon the stabilized output quantity, all other influence quantities being held constant or within a range of values such that their cumulative influence on the stabilized output quantity is negligible. For purpose of measurement, the magnitude on the cumulative effect of all other influence quantities shall be less than one-tenth of the specified magnitude of the effect being observed.

2.2 The combined limit of error, composed of instrumentation accuracy and the cumulative effect of spurious influences, shall be regarded as the limiting tolerance on the accuracy of each measurement result.

2.3 When measurements are made for the purpose of establishing a value or specification, the value obtained shall be considered to be uncertain by an amount equal to this tolerance.

2.4 When measurements are made for the purpose of verification, the value shall be considered as verified if it does not exceed the limits of the specification by an amount equal to this tolerance.

3. INSTRUMENTATION

3.1 Measuring apparatus shall have sufficient resolution, stability and accuracy so as to insure a limit of error not exceeding 10 percent of the measured effect specification. For each test, though not individually specified, sufficient metering and monitoring shall be provided so as to insure compliance with the test conditions.

4. CONDITIONS OF MEASUREMENT

4.1 Quantities not described in the individual tests are as specified under reference conditions in IS : 7204 (Part II)-1980*, Tables 1 and 2, ' Tolerance G '.

*Specification for stabilized power supplies, dc output : Part II Rating and performance.

5. SET OF TEST DATA

5.1 Measurements on variable-output supplies, subject to a variety of loads and other influences, inevitably require repetition of tests to form a set of data corresponding to the possible combination of outputs and important influences.

5.2 The individual test procedures will suggest a minimum set of tests, designed to yield data at situation extremes. Additional testing at closer data points to provide more information may be undertaken optionally.

6. TIME SEPARATION

6.1 The response to a sudden changing influence will, in general, have three parts: a transient phase, a steady-state phase, and (possibly) a settling phase.

6.2 The transient phase is characterized by an amplitude and time measurement and may be influenced by the rate at which the event occurs. The steady-state phase is, generally, the response of interest — the object of most test measurements. The settling phase represents the re-establishment of system equilibrium with its environment following changed operating conditions and is usually observed when altered dissipation requires establishment of a new thermal equilibrium.

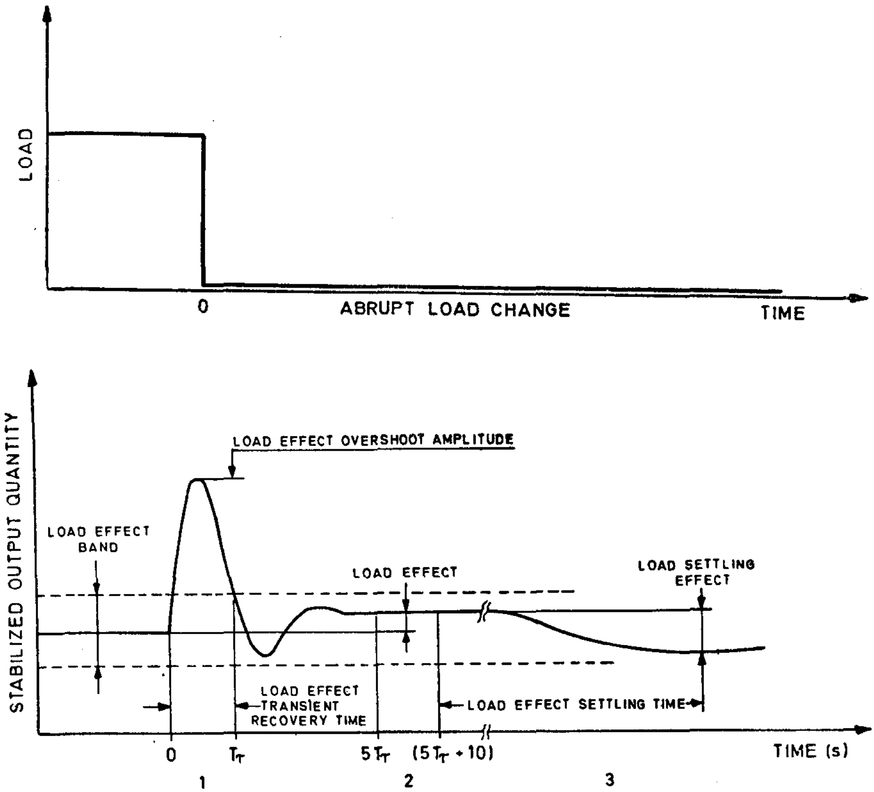
6.3 Since measurement of a transient effect is quite different from the measurement of a steady-state effect, and because all of the transient effects are similar, a separate test for transient effects is described (*see* **13**) and the individual transient effects are excluded from the steady-state measurements.

7. LOAD EFFECT

7.1 Load effect is measured as the change in the stabilized output quantity caused by changes in load. All other influence quantities are held such that their cumulative influence is less than one-tenth of the load effect specification. The steady-state load effect is considered to exist at a time equal to 5 times the load effect recovery time and should be measured during the interval between $5T\tau$ and ($5T\tau + 10$ s) (*see* Fig. 1).

7.2 Conditions of Measurement — The requirements given in **4** shall apply.

7.2.1 *Source* — Load effect measurements shall be made with the source voltage set to the lowest rated value and repeated with the voltage set to the highest rated value.



1 = Load effect transient
2 = Load effect
3 = Load settling effect

Fig. 1 Three Time Separable Output Effects Following A Step Load Change

7.2.2 *Output*

7.2.2.1 *Stabilized output quantity* — If the power supply offers a selection of output settings, conduct the load effect measurement at maximum rated value and repeat with the stabilized output quantity set to minimum rated value. If the minimum value is zero, conduct the measurement at 1 percent of maximum value.

7.2.2.2 *Load* — The variable influence quantity for this measurement is the load quantity (current or voltage) which is varied within its rated range and other ranges for which a load effect is specified.

7.2.2.3 *Multiple output power supplies* — Conduct a series of load effect measurements for each output with all other outputs set simultaneously to minimum and then to maximum value and loaded to the minimum and maximum amount.

7.3 Equipment Required

7.3.1 A means for detecting changes in the value of the stabilized output quantity. In order to observe a small change in the presence of a large static quantity, a differential instrument or balancing arrangement is recommended with suitable precautions to avoid exceeding the common mode rating of the instrument.

7.3.2 A means of loading the power supply capable of switching through the range of required loads.

7.3.3 For measurements on current stabilized power supplies, a suitable current monitoring means. A suggested means is a 4-terminal resistor chosen to drop the minimum voltage consistent with the 10 percent limit of error.

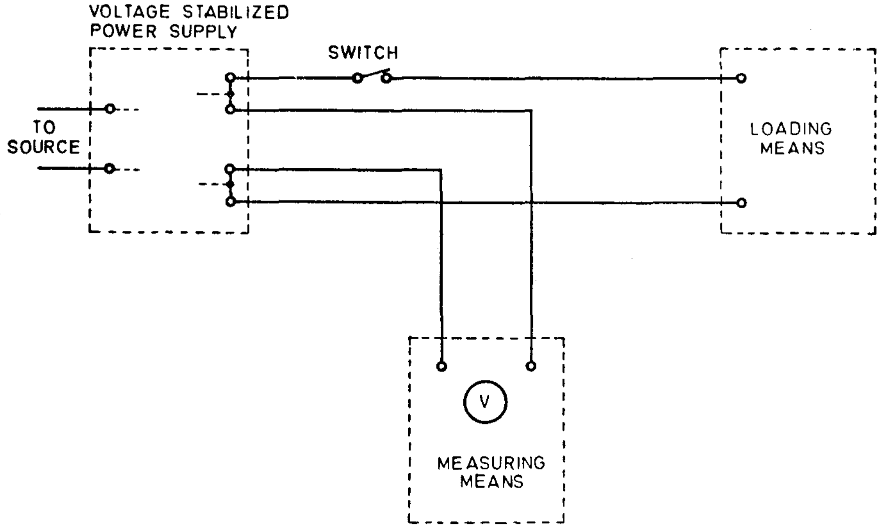
7.3.4 In the case where power supply under test cannot operate in the absence of a load, it should be assured before switching on that a minimum permanent safety load is applied to the output. This may be achieved by permanently connecting the load or incorporating a suitable built in circuit.

7.4 Set-up and Procedure (Voltage-Stabilized Power Supplies)

7.4.1 Connect load and measuring apparatus to the output terminals of the power supply (*see* Fig. 2) in such a way that the current drawn by the load causes negligible error in the measured voltage.

In practice, a 4-terminal connection will be used such that the monitoring circuit does not include any conductor or part thereof that is also carrying load current.

7.4.2 Make the load effect measurement by varying the load current through its rated or specified range. Measure the amplitude of the change in the stabilized output voltage during the interval $5T\tau$ to ($5T\tau + 10s$) following the load change. The load current should be varied from minimum to maximum and then from maximum to minimum, with a separate recording of value made for each direction. Repeat for each combination of source voltage and output setting to obtain a set of data.



NOTE — If separate 'Error Sensing' terminals are provided on the power supply, connect the 'Measuring Means' there.

FIG. 2 LOAD EFFECT MEASUREMENT SET-UP, VOLTAGE-STABILIZED POWER SUPPLY

7.5 Set-up and Procedure (Current-Stabilized Power Supply)

7.5.1 Connect the current monitoring means so that its indication is exclusively proportional to current. Connect the load in such a way that the voltage dropped across it causes negligible error in the measured current (*see* Fig. 3).

7.5.2 Make the load effect measurement by varying the load voltage through rated or specified range. Measure the amplitude of the change in the stabilized output current during the interval $5T\tau$ to ($5T\tau + 10s$) following the load change. The load voltage should be varied from minimum to maximum and then from maximum to minimum with a separate recording of value made for each direction. Repeat for each combination of source voltage and output setting to obtain a set of data.

7.6 Presentation of Results — Express the load effect either as a percentage of a maximum output — or in units of a volt (or fractions thereof) for voltage-stabilized power supplies, or in units of an ampere (or fractions thereof) for current-stabilized power supplies. To express the load effect for variable output power supplies, both a percentage and absolute value shall be used.

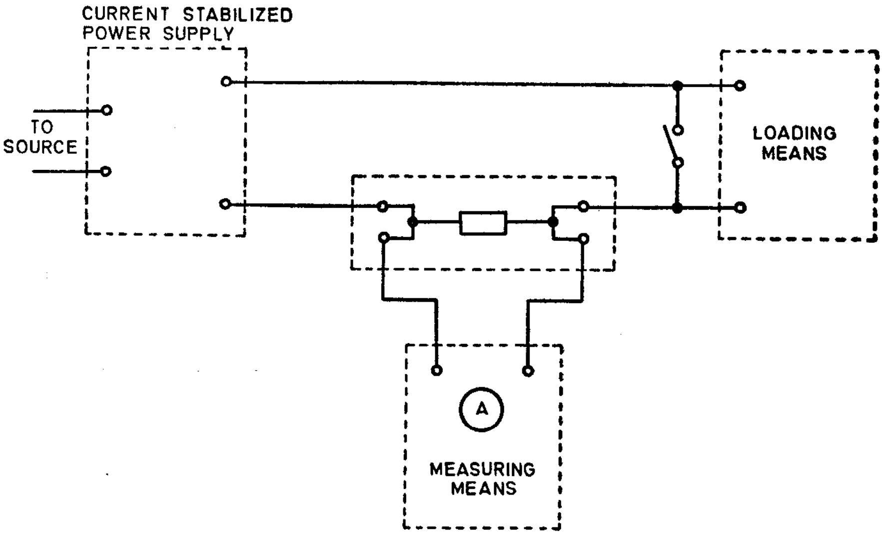
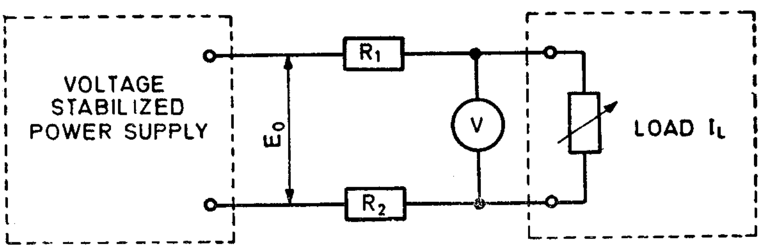


FIG. 3 LOAD EFFECT MEASUREMENT SET-UP, CURRENT-STABILIZED POWER SUPPLY

7.7 Alternates, Precautions and Error Analysis

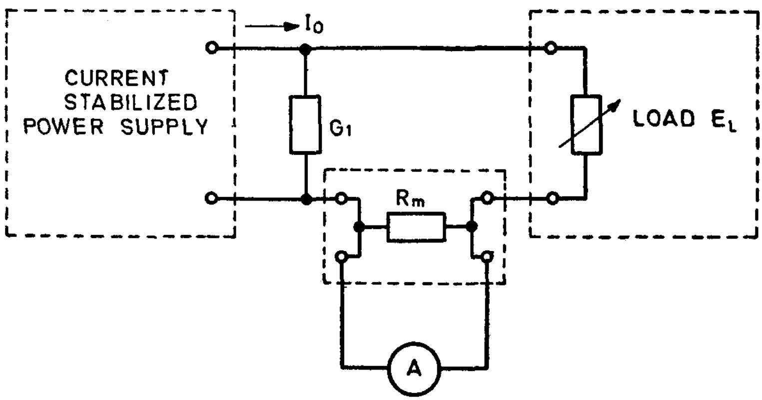
7.7.1 In measuring load effect on voltage stabilized supplies, avoid series resistance in the load path between the measuring point and the power supply output terminals. Care should be exercised in the placement of ammeters and leads to avoid such series resistance (*see* Fig. 4).



NOTE — Resistances R_1 and R_2 degrade the apparent load effect measurement by I_L (R_1 + R_2). Such resistance should be avoided.

FIG. 4 INCORRECT USE OF RESISTANCE IN VOLTAGE-STABILIZED POWER SUPPLY

7.7.2 In measuring load effect on current stabilized supplies, avoid shunt conductance across the load terminals between the measuring point and the power supply output terminals. Care should be exercised in the placement of voltmeters and other instrumentation to avoid such shunt conductance (*see* Fig. 5).



NOTE — Conductance G_1 degrades the apparent load effect measurement by $(E_L + R_m I_O)G_1$. Such conductance should be avoided.

FIG. 5 INCORRECT USE OF RESISTANCE IN CURRENT-STABILIZED POWER SUPPLY

7.7.3 When measuring voltage or current limited power supplies, or power supplies with combined characteristics (crossover point), care should be taken to insure that the stabilized output quantity is not limited by the power supply's bounding circuit for any combination of source, output or load conditions of the test.

7.7.4 The voltage drop in the current monitoring resistor, used for measurements on current stabilised power supplies, unavoidably restricts the amount of load voltage range, limiting the minimum load voltage to a non-zero value. This instrumentation limit is to be considered in making an error analysis.

8. SOURCE EFFECT

8.1 Source effect is measured as the change in the stabilized output quantity caused by a change in the source voltage. All other influence quantities are held such that their cumulative influence is less than one-tenth the source effect specification. The steady-state source effect is considered to exist at a time equal to 5 times the source effect recovery time and should be measured during the interval between $5T_\tau$ and ($5T_\tau + 10s$) similar to Fig. 1 with the load step change replaced by a source step change.

8.2 Conditions of Measurement — The requirements given in **4** shall apply.

8.2.1 *Source* — The variable influence quantity for this test is the source voltage which is varied within its rated and other ranges for which source effect is specified.

8.2.2 *Stabilized Output Quantity*

8.2.2.1 If the power supply offers a selection of output settings, conduct the source effect test at maximum rated value and repeat with the stabilized output quantity set to the minimum rated value. If the minimum rated value is zero, conduct the test at 1 percent of maximum value.

8.2.2.2 *Load* — Two load settings should be used to create a set of data for the source effect measurement as follows:

a) Minimum or zero load, and

b) Maximum load.

8.2.2.3 *Multiple output power supplies* — Conduct a series of source effect measurements for each output with all other outputs set simultaneously to minimum and then to maximum value and loaded to the minimum and maximum amount.

8.3 Equipment Required

8.3.1 A source of primary energy for the power supply capable of varying the magnitude of the source voltage between the specified limits and of sufficient rating so that the loading imposed by the power supply does not result in significant change in either source amplitude or distortion.

8.3.2 A means of detecting changes in the stabilized output quantity. In order to observe a small change in the presence of a large static quantity, a differential instrument or balancing arrangement is recommended with suitable precautions to avoid exceeding the common mode rating of the instrument.

8.3.3 A suitable means for current monitoring in case of current stabilized power supplies is a 4-terminal resistor chosen to drop the minimum voltage consistent with the 10 percent limit of error.

8.4 Set-up and Procedure (Voltage-Stabilized Power Supplies)

8.4.1 Connect load and measuring apparatus to the output terminals of the power supply in such a way that the current drawn by the load

causes negligible error in the measured voltage. In practice, a 4-terminal connection will be used. Connect the power supply to the variable source (*see* Fig. 6).

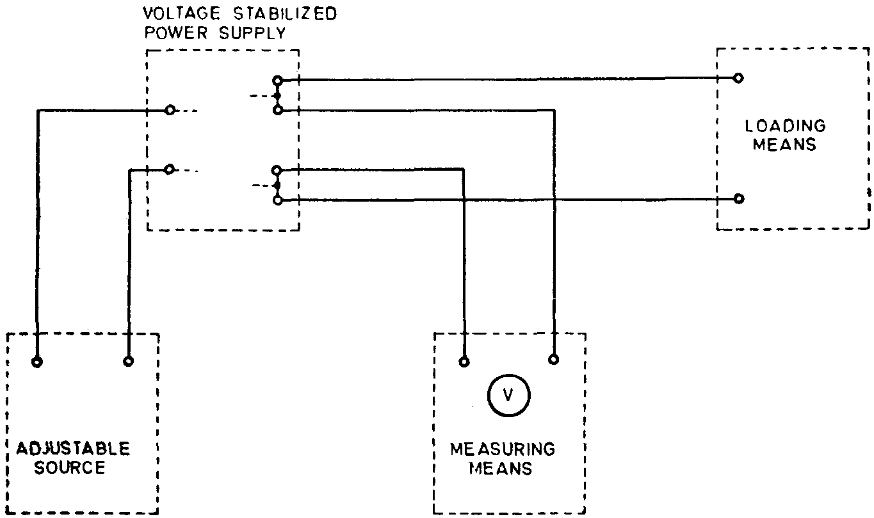


FIG. 6 SOURCE EFFECT MEASUREMENT SET-UP, VOLTAGE-STABILIZED POWER SUPPLY

8.4.2 Make the source effect measurement by varying the source voltage magnitude throughout its rated or specified range. Measure the amplitude of the change in the stabilized output voltage during the interval $5T\tau$ to ($5T\tau + 10s$) following the step change in the source voltage. Repeat for each combination of output voltage and load current to obtain a set of data.

8.5 Set-up and Procedure (Current-Stabilized Power-Supplies)

8.5.1 Connect the current monitoring means so that its terminal voltage (or indication) is exclusively proportional to current. Connect the load in such a way that the voltage dropped across it causes negligible error in the measured current (*see* Fig. 7).

8.5.2 Make the source effect measurement by varying the source voltage magnitude throughout its rated or specified range. Measure the amplitude of the change in the stabilized output current during the interval $5T\tau$ to ($5T\tau + 10s$) following the step change in the source voltage. Repeat for each combination of output current and load voltage to obtain a set of data.

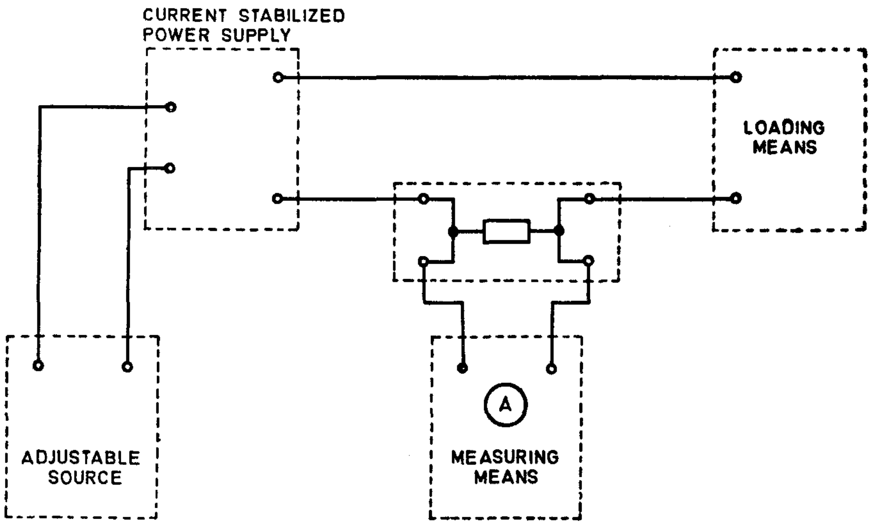


FIG. 7 SOURCE EFFECT MEASUREMENT SET-UP, CURRENT-STABILIZED POWER SUPPLY

8.6 Presentation of Results — Express the source effect in terms of the percentage change of the stabilized output quantity and/or as the absolute magnitude of the measured change in the units of the stabilized output quantity.

8.7 Alternates, Precautions and Error Analysis

8.7.1 In measuring the source effect on voltage or current limited, or automatic crossover power supplies, care should be taken to insure that the stabilized output quantity is not limited by the power supply's bounding circuits for any combination of source, output or load condition of this test.

8.7.2 The voltage drop in the current monitoring resistor used for measurements on current stabilized power supplies unavoidably restricts the amount of load voltage range, limiting the minimum load voltage to a non-zero value. The instrumentation limit is to be considered in making an error analysis.

8.7.3 If the power supply source connection is accomplished via terminals provided by the manufacturer, measurement of the source voltage should be made at these terminals. Otherwise, measurement of

the source voltage is to be accomplished at the plug end of the power cord which the manufacturer provides or recommends for use with the power supply.

9. PERIODIC AND RANDOM DEVIATION (PARD)

9.1 PARD is measured as the unprogrammed fluctuations in the stabilized output quantity of a power supply (previously ' ripple and noise '). PARD is composed of such fluctuations as occur in the frequency range 20 Hz to 10 MHz. Fluctuations below 20 Hz are treated as drift (*see* **10**) and those above 10 MHz are excluded.

9.2 Conditions of Measurement

9.2.1 The requirements given in **4** shall apply.

9.2.2 *Source Amplitude* — PARD measurement shall be made with the source voltage set to the lowest specified value and repeated with the source voltage set to the highest specified value.

9.2.3 *Source Frequency* — PARD measurement shall be made at the highest specified nominal source frequency and repeated at the lowest specified nominal source frequency.

9.2.4 *Stabilized Output Quantity* — If the power supply offers a selection of output settings, conduct the PARD measurement at the maximum rated value and repeat with the stabilized output quantity set to minimum rated value. If the minimum value is zero, conduct the test at 1 percent of maximum value.

9.2.5 *Load* — Two load settings shall be used in generating the data set for the PARD measurement with the load set to its maximum rated value and a second with the load set to its minimum rated value.

9.2.6 *Multiple Output Power Supplies* — Conduct the series of PARD measurements for each output with all other outputs set simultaneously to minimum and then to maximum value and loaded to the minimum and maximum amounts.

9.3 Equipment Required

9.3.1 A source of primary energy for the power supply capable of producing the rated extremes of both voltage and frequency, and of such construction that the loading imposed by the power supply does not result in significant change in either source voltage or distortion.

9.3.2 A means of loading the power supply capable of switching through the range of required loads.

9.3.3 A suitable means for current monitoring for use in case of current stabilized power supplies. A suggested means is a 4-terminal resistor, chosen to drop the minimum voltage consistent with the 10 percent limit of error.

The current monitoring resistor shall be of non-reactive construction such that its impedance remains essentially constant over the 20 Hz to 10 MHz range. A comparison of its impedance at 10 MHz with its impedance at 20 Hz shall exhibit a difference less than one-tenth of the dc resistance, otherwise the test data shall be compensated for frequency.

9.4 Set-up and Procedure

9.4.1 Connect the variable source and loads(s) to the power supply and monitor the PARD amplitude in the stabilized output quantity. For current stabilized power supplies, use the current monitoring means.

9.4.2 Set the source voltage, source frequency, stabilized output and load to each specified value and repeat for each combination to form a set of data on PARD.

9.5 Presentation of Results — Express PARD in voltage units for voltage stabilized power supplies, and in ampere units for current stabilized power supplies.

9.6 Alternates, Precautions and Error Analysis

9.6.1 A single ground point shall be used to avoid loops. Care shall be exercised to be certain that the ground current does not flow in any conductor that also forms part of the PARD measuring circuit.

9.6.1.1 Suitable safety precautions shall be taken to ensure the continuity of the grounding connection.

9.6.2 If differential-input measuring equipment is used, care shall be exercised to ensure that the rated common mode voltage is not exceeded and that the error introduced by the common mode signal, multiplied by the instrument's rejection ratio, when combined in absolute magnitude with all other effects does not exceed 10 percent of the PARD specification.

9.6.3 The voltage drop in the current monitoring resistor used for PARD measurements on current stabilized power supplies, unavoidably restricts the minimum load voltage to a non-zero value. This is an instrumentation error and is to be considered in making an error analysis.

9.6.4 Shield as required, to prevent noise pickup from contributing a PARD component in excess of the 10 percent cumulative limit of error.

9.6.5 For PARD measurements on voltage limited or current limited or automatic crossover power supplies, care shall be taken to ensure that the controlled output quantity is not limited for any combination of source, output or load conditions of the test.

10. DRIFT

10.1 Drift is measured as the change in the stabilized output quantity during a specified period of time, following warm-up, all other influence quantities held such that their cumulative influence is less than one-tenth of the drift specification. The drift measurement includes output perturbations in the frequency range dc to 20 Hz.

10.2 Conditions of Measurement

10.2.1 The requirements given in **4** shall apply.

10.2.2 *Stabilized Output Quantity* — If the power supply offers a selection of output settings, conduct the drift measurement at maximum rated value and repeat with the stabilized output quantity set to minimum rated value. If the minimum value is zero, conduct the measurement at 1 percent of maximum value.

10.2.3 *Load* — Two methods are employed as follows:

Method I — Set the load to the maximum rated value, and

Method II — Operate the power supply unloaded.

10.2.4 *Multiple Output Power Supplies* — Two methods are employed as follows:

Method I — Conduct the drift measurements with all outputs loaded to their maximum outputs, and

Method II — Conduct the drift measurement with all outputs unloaded.

10.3 Equipment Required

10.3.1 A means for detecting changes in the value of the stabilized output quantity whose own variations (drift) over the period of observation are sufficiently small that, combined in absolute magnitude with all other effects, they do not introduce a limit of error exceeding one-tenth of the power supply's drift specification.

The measuring means shall respond to perturbations in the frequency range from dc 0 to 20 Hz and shall exclude signals over 20 Hz by means of a low pass filter whose response falls by at least a 6 dB per octave.

A strip chart read out of the measured changes in stabilized output quantity is recommended. If the upper frequency cutoff of the recorder is

less than 20 Hz, supplemental observation shall be made with a cathode-ray oscilloscope, fitted with a 20 Hz low pass filter. Such observation shall be made for a period of 5 minutes, once during the first hour of the measurement and again during the last hour.

10.3.2 A means for controlling the environment (particularly the temperature of the power supply such that the temperature effect, combined in absolute magnitude with all other effects, does not contribute an error exceeding one-tenth of the power supply's drift specification.

10.3.3 A suitable means for current monitoring for use in case of current-stabilized power supplies. A suggested means is a 4-terminal resistor chosen to drop the minimum voltage consistent with the 10 percent limit of error.

10.4 Set-up and Procedure

10.4.1 Operate the power supply under test conditions for the specified warm-up period. If no warm-up time is specified, allow 1/2 hour for warm-up. During this period, adjust output setting, load, source and measuring instruments. No adjustments may be made once measurements have begun.

The completion of the turn-on transient settling effect (warm-up) should be determined by the method given in **14**.

10.4.2 Record the changes in the stabilized output quantity for the specified interval of time. If no duration is specified, the recording shall be for a minimum period of 8 hours. During this period, the values of source voltage, load and environmental temperature shall be recorded at intervals not greater than 30 minutes. For current stabilized power supplies, employ the current monitoring means.

10.4.3 The drift is the absolute measured difference between the maximum and minimum values of the stabilized output quantity occuring within the measurement time span. Report as a percentage change or in the units of the stabilized output quantity that is, volts or amperes or fractions thereof.

10.4.4 The drift measurement shall be identified as having been made in accordance with Method I (*see* **10.2.3** and **10.2.4**), if it is accomplished in a temperature-controlled environment, fully loaded.

10.4.5 Identify the drift measurement as being in accordance with Method II (*see* **10.2.3** and **10.2.4**) if it is accomplished in a temperature-controlled environment not loaded.

10.4.6 In the event that a temperature-controlled environment cannot be provided, conduct the drift measurement as follows and identify the results as Method III.

10.4.6.1 *Method III* — Construct a draft shield, each dimension 1 m greater than that of the power supply and set up in the best air-conditioned space available. Measure the temperature at three points in the space surrounding the power supply and average. Multiply the observed (average) temperature change from the maximum to the minimum value during the drift measurement interval by the power supply's temperature effect coefficient and subtract the magnitude of the product from the magnitude of the observed change in the stabilized output quantity.

For Method III, the power supply should be operated so loaded as to minimize the self-heating of the immediate environment.

10.5 Alternates, Precautions and Error Analysis

10.5.1 When measuring the drift of a stabilized output current, if necessary, the monitoring means shall be maintained in a temperature-controlled environment so that changes in its value combined in absolute magnitude with all other effects affect the drift measurement by an amount less than one-tenth of the power supply's drift specification.

10.5.2 For measurements on voltage limited or current limited or automatic crossover power supplies, care should be taken to ensure that the controlled output quantity is not limited for any combination of source, output and load condition of the test.

11. OUTPUT IMPEDANCE

11.1 Output impedance is measured as the ratio of the amplitude of a sinusoidally changing output voltage to the amplitude of the changing output current. It is the dynamic load effect, measured in the frequency domain. The output impedance is, generally, a variable function of frequency and is expressed by describing the function for a specified band of frequencies.

11.2 Conditions of Measurement — The requirements given in **4** shall apply.

11.2.1 *Stabilized Output Quantity* — If the power supply offers a selection of output settings, conduct the output impedance measurement at maximum rated value.

11.2.2 *Load* — The variable influence quantity for the output impedance measurement is the load which is varied or modulated in sinusoidal fashion

about a fixed value equal to 50 percent of its specified maximum or rated value.

11.2.2.1 The modulation amplitude shall not be larger than what is sufficient for the measurement of the sinusoidal response variations in the stabilized output quantity, but shall not exceed 100 percent. That is, the peak value of the varying load shall not exceed the maximum rating of the power supply, nor shall it go below zero or become negative.

11.2.3 *Modulation Frequency* — The load shall be modulated over a sufficient band of frequencies so as to encompass any frequency for which information is required. In any event, the band of modulation frequencies shall be sufficient so as to clearly define the slope (rate of change) of output impedance versus frequency.

11.2.4 *Number of Measurements* — Plotting points shall be sufficiently close so as to adequately depict irregularities or discontinuities in the output impedance slope.

11.3 Equipment Required

11.3.1 A source of primary energy for the power supply of sufficient rating that the modulated loading imposed by the power supply does not result in significant change in source voltage. Particularly, source voltage changes in synchronism with the modulation waveform multiplied by the source effect, shall contribute to a cumulative error less than one-tenth the specified output impedance at the frequency.

11.3.2 A means for loading the power supply capable of being modulated over the required frequency range:

a) *For voltage-stabilized power supplies* — The load may take the form of a low impedance power amplifier, able to swing the required current and suitably decoupled from the dc voltage of the power supply, in parallel with a resistive load set to draw 50 percent of the rated current.

b) *For current-stabilized power supplies* — The load may take the form of a high impedance power amplifier, able to swing the required voltage, and suitably decoupled for the dc current of the power supply, in series with a resistive load set to support 50 percent of the rated voltage.

11.3.3 *A Current Monitoring Means* — A suggested means is a resistor chosen to develop a voltage proportional to the ac current amplitude. The current-monitoring resistor shall be sufficiently non-reactive that a comparison of its impedance at the highest modulation frequency with its impedance at the lowest modulation frequency, exhibits a difference less than one-tenth of the dc resistance.

11.3.4 A sinewave generator having the required frequency range and sufficient output amplitude to drive the modulation of the load.

11.3.5 A means of observation, preferably an oscilloscope having two identical channels so that voltage and current may be monitored simultaneously. The bandwidth shall be sufficient for the frequency range being used. Resolution, sensitivity, stability and accuracy shall be sufficient to ensure a limit of error not in excess of 10 percent of the output impedance specification.

11.4 Set-up and Procedure

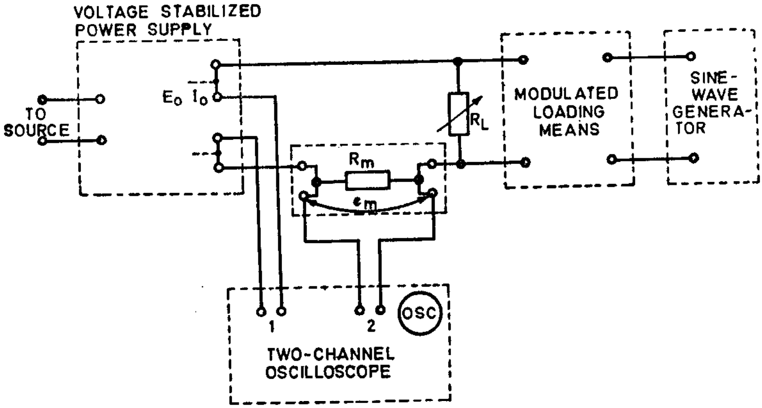
11.4.1 *For Voltage-Stabilized Power Supplies* — Connect the load and current monitoring means to the power supply as shown in Fig. 8. Modulation current amplitude should be adjusted for at least a 20 dB signal-to-noise ratio for the responsive voltage amplitude (E_{sin}) but shall not exceed 100 percent. Usually this will determine the lowest frequency that can be modulated. An additional plotting point at dc can be obtained from the load effect measurement by computing $\Delta E_{sin} / \Delta I_{sin}$.

11.4.1.1 The output impedance is obtained by measuring the modulating current amplitude I_{sin}, the responsive voltage amplitude E_{sin} and computing $Z_2 = \dfrac{E_{sin}}{I_{sin}}$.

11.4.1.2 This measurement is repeated at spaced frequency intervals over the frequency band to permit the drawing of a smooth curve through the locus of output impedance points. The impedance locus may be drawn on log-log graph paper so that the slope of the impedance *versus* frequency will permit identification of the equivalent output reactance. The typical plots of impedance *versus* frequency are shown in Fig. 9.

11.4.2 *For Current-Stabilized Power Supplies* — Connect the load and current monitoring means to the power supply as shown in Fig. 10. Modulation voltage amplitude should be adjusted for at least 20 dB signal-to-noise ratio for the responsive current (I_{sin}), but shall not exceed 100 percent. Usually this will determine the lowest frequency that can be modulated. An additional plotting point at dc can be obtained from the load effect measurement by computing $\Delta E_{sin} / \Delta I_{sin}$.

The output impedance is obtained by measuring the modulating voltage amplitude e_0 the responsive current amplitude, I_{sin}, and the computing $Z_2 = \dfrac{E_{sin}}{I_{sin}}$.



NOTES—

1. Choose R_L to draw a fixed load current equal to 50% of the rated value I_c
2. *Measurement on:*

   Channel 1, Voltage Waveform E_{sin}

   Channel 2, Current Waveform I_{sin}

   $$\boxed{Z_2 = \frac{E_{sin}}{I_{sin}}}$$

3. Use independent oscilloscope inputs or differential 2-Channel instrument or connect R_m to power supply's output terminal with minimum length such that error from common mode voltage is less than 10% of the measured value.

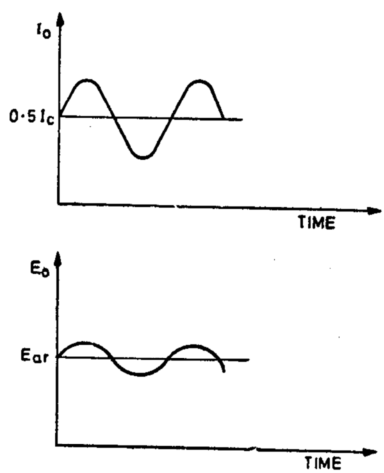
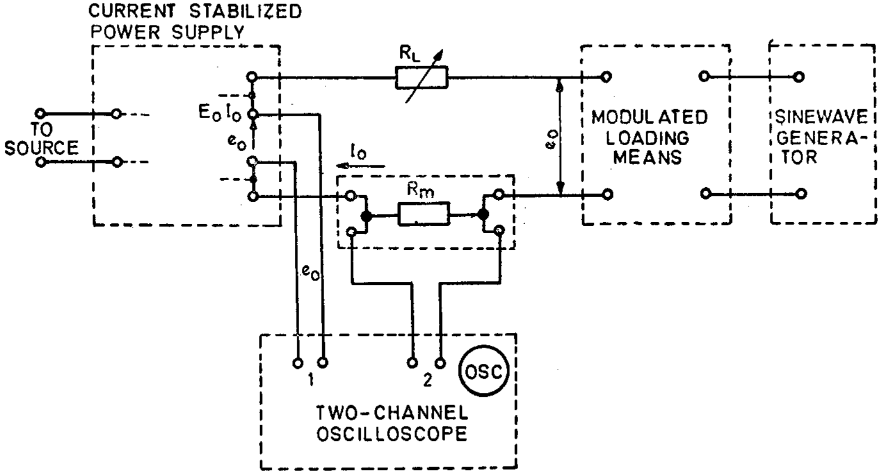


FIG. 8 SET-UP FOR VOLTAGE-STABILIZED POWER SUPPLY



Measurements:

Channel 1, Voltage Waveform E_{sin}

Channel 2, Current Waveform I_{sin}

$$\boxed{Z_2 = \frac{E_{sin}}{I_{sin}}}$$

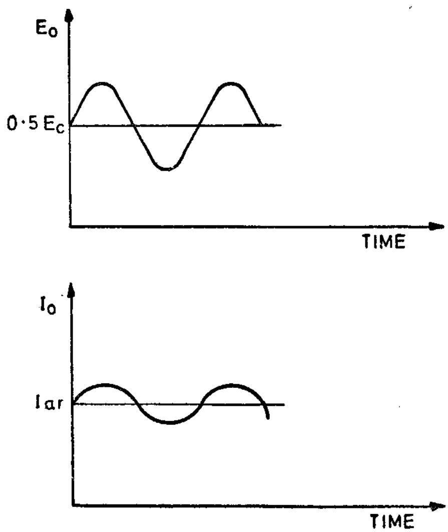
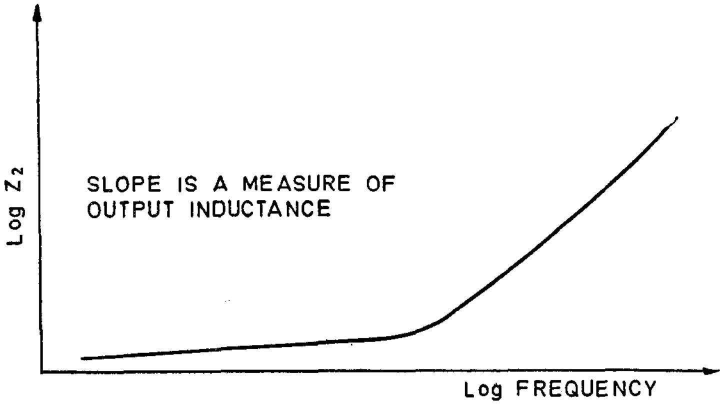
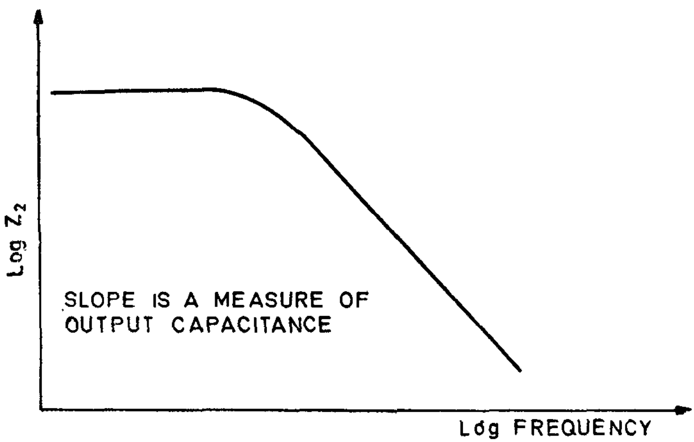


FIG. 9 SET-UP FOR CURRENT-STABILIZED POWER SUPPLY



10A Typical Voltage-Stabilized Power Supply



10B Typical Current-Stabilized Power Supply

FIG. 10 TYPICAL PLOTS OF IMPEDANCE *VERSUS* FREQUENCY

11.5 Alternates, Precautions and Error Analysis

11.5.1 Care shall be exercised so that the PARD amplitude is not mistaken for the responsive signal in the stabilized output quantity. The use of frequency discriminatory filters may aid measurement.

11.5.2 Use short, twisted wires to connect the load and measuring means in a 4-terminal connection to the power supply. Reactance in the load or measuring circuit may be determined and discounted by repeating the measurements on a short circuit in place of the voltage stabilized power supply, and an open circuit in place of the current stabilized power supply.

11.5.3 The modulation signal shall always be in the form of a low distortion sinusoid. Reduce the modulation amplitude if noticeable distortion appears at any frequency.

11.5.4 For measurements on voltage limited or current limited or automatic crossover power supplies, care should be taken to ensure that the controlled output quantity is not limited for any modulation amplitude, nor should the load be permitted to go below zero.

12. TEMPERATURE EFFECT

12.1 The temperature effect is the steady-state change of a power supply's stabilized output quantity following a change in the ambient temperature. After temperature is varied, there are two ensuring, time separable output effects as follows (*see* **6**):

a) A transient output perturbation and recovery (*see* **13**), and

b) The steady-state temperature effect.

12.1.1 This procedure is concerned with the measurement of the temperature effect coefficient, the maximum steady-state change in stabilized output quantity per unit of temperature (usually 1°C).

12.2 Conditions of Measurement — The requirements given in **4** shall apply.

12.2.1 *Environment (Temperature)* — The variable influence quantity for this test is the temperature which is to be varied in increments of 10°C over the specified temperature range.

12.2.2 *Stabilized Output Quantity* — If the power supply offers a selection of output settings, conduct the temperature effect (coefficient) measurement at maximum rated value and repeat with the stabilized output quantity set to minimum rated value. If the minimum value is zero, conduct the measurement at 1 percent of maximum value.

12.2.3 *Load* — Two methods are employed:

Method I — Set the load to maximum rated value.

Method II — Operate the power supply so loaded as to minimize the self-heating.

12.2.4 *Multiple Output Power Supplies* — Two methods are employed:

Method I — Conduct the temperature effect (coefficient) measurement with all outputs loaded to their maximum output.

Method II — Conduct the temperature effect measurement with all outputs so loaded as to minimize the self-heating.

12.3 Equipment Required

12.3.1 A means for controlling the environmental temperature over the range of temperatures specified in 10°C increments, accurate to 1°C.

12.3.2 A means for detecting changes in the value of the stabilized output quantity such that the time (T_2) at which thermal equilibrium is achieved can be determined. A device that makes a continuous record of its readings, such as a strip-chart recorder, is recommended. Said means is to have sufficient resolution, stability and accuracy so that its error, combined in absolute magnitude with all other effects, insures a limit of error not to exceed 10 percent of the temperature effect (coefficient) specification.

12.3.3 For measurements on current stabilized power supplies, a current monitoring means is required. A suggested means is a 4-terminal resistor chosen to drop the minimum voltage consistent with a limit of error not to exceed 10 percent of the temperature effect coefficient specification.

12.4 Set-up and Procedure

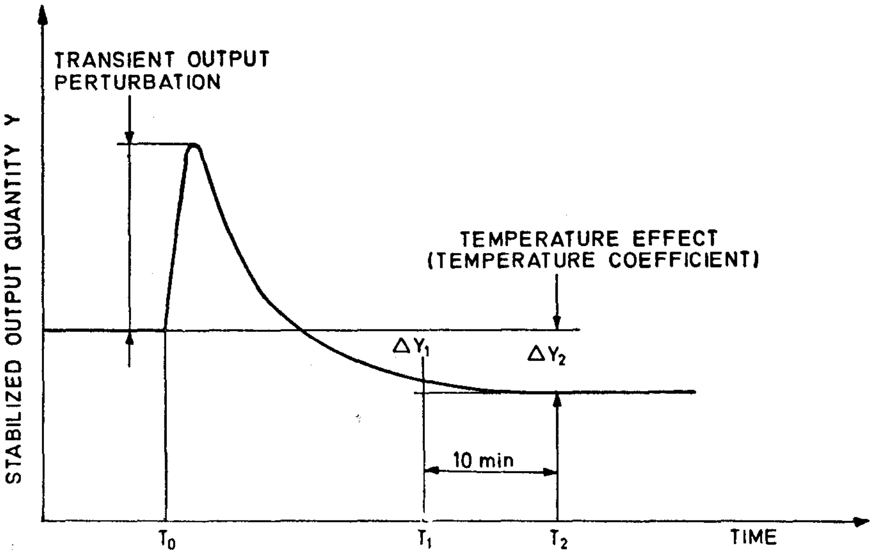
12.4.1 *For Voltage-Stabilized Power Supplies* — Connect the load and monitoring equipment to the power supply with a 4-terminal connection and place the power supply in a temperature-controlled environment.

12.4.2 *For Current-Stabilized Power Supplies* — Connect the current monitoring means so as to make its indication proportional to the output current. Measuring equipment shall be connected to the monitoring device by means of a 4-terminal connection. The power supply is placed in a temperature-controlled environment. The current monitoring elements shall remain outside of the variable-temperature environment.

12.4.3 The temperature effect measurement is accomplished by raising the temperature of the environment in steps of 10 ± 1°C from the lowest specified temperature to the highest specified temperature, and then reducing the temperature of the environment in steps of 10°C from the highest specified temperature to the lowest specified temperature.

If not otherwise specified, the range of temperatures over which the temperature effect coefficient measurements are to be made are equal to the operating temperature range of the power supply.

12.4.4 At each step the temperature shall be held constant $\pm$ 1°C until the value of the output quantity has reached equilibrium (T_2, *see* Fig. 11). For the purpose of this test, it shall be considered that equilibrium is reached when the stabilized output quantity varies by an amount less than 5 percent of the total change over a 10 minute period.



$T_2 = T_1 + 10$ min

T_1 = Time for which $\Delta Y_2 \leqslant 0.05\ \Delta Y_1$

FIG. 11 TEMPERATURE EFFECT

12.4.5 *Reporting of Result* — Express the temperature effect coefficient as the measured change in the stabilized output quantity at T_2, compared with T_0, divided by 10(°C). The set of observations for ascending and descending temperatures at the two settings of the stabilized output quantity constitute the set of temperature effect coefficient measurements which shall be reported in terms of the largest percentage change per unit of temperature (percent per °C) or the largest measured change in the units of the stabilized output quantity per unit of temperature ($\Delta\gamma / \Delta\theta$).

12.4.6 Identify the temperature effect (coefficient) measurement as being in accordance with Method I (*see* **12.2.3** and **12.2.4**), if it is accomplished in a temperature-controlled environment, fully loaded.

12.4.7 In the event of lack of facilities or power supply size make a fully loaded sample test inside a controlled-temperature chamber impractical, tests may be conducted with the power supply so loaded as to minimize the self-heating. If this method is used it shall be reported as Method II (*see* **12.2.3** and **12.2.4**).

12.5 Alternates, Precautions and Error Analysis

12.5.1 For current stabilized power supplies, the current monitoring means shall be placed in an environment outside of the test chamber.

12.5.2 For measurements at high temperatures, care shall be exercised to ensure compliance with manufacturer's requirements concerning heat flow so as to ensure that the local temperature of the power supply is within specified bounds.

12.5.3 Errors caused by drift perturbations shall be accounted for in making the temperature coefficient measurement.

13. TRANSIENT PERFORMANCE MEASUREMENT

13.1 A power supply's transient performance describes the behaviour of its stabilized output quantity immediately following a step change in any influence quantity. A transient performance measurement includes both the amplitude of the disturbance in the stabilized output quantity and the time for its recovery.

13.1.1 Influence quantities for which transient performance measurements may be made include, but are not limited to:

a) Step load changes,
b) Step source voltage changes, and
c) Step changes in ambient temperature.

13.1.2 For the purpose of this test, a step change in an influence quantity shall be effected in a time interval not greater than one-tenth of the specified recovery time and shall be monotonic, having no overshoot or ringing.

13.1.3 It is realized that these requirements may be difficult to meet for high power units. Accordingly the scope of this test is limited to cases where adequate equipment is available.

13.2 Conditions of Measurement — The requirements given in **4** shall apply.

13.2.1 *Stabilized Output Quantity* — If the power supply offers a selection of output settings, conduct the transient measurement at maximum rated value.

13.2.2 *Load* — If the influence quantity cannot be stepped, set the load to maximum specified value.

13.2.3 *Multiple Output Power Supplies* — Conduct transient measurements with all outputs set and loaded to their maximum rated value.

13.3 Equipment Required

13.3.1 If the source voltage is the influence quantity to be stepped suddenly, a mechanism to provide a step change between the minimum and the maximum rated source voltages will be required. These may either be the two voltage extremes or from the mid voltage to either extreme.

13.3.2 If load is the influence quantity to be stepped suddenly the loading means shall be capable of being changed abruptly between the minimum and maximum value of load. If mechanical means are chosen, they shall be capable of interrupting the load circuit without sustaining an arc. Because of the difficulty in doing this, electronic load switching means are recommended.

13.3.3 If temperature is the influence quantity being stepped suddenly a controlled environment will be required, capable of executing fast changes in temperature over a specified temperature range.

13.3.4 A means for measuring the amplitude of the transient effect and time required for its recovery. An oscilloscope is the recommended instrument, calibrated in the amplitude and time base, with sufficient accuracy and resolution so as to ensure a limit of error not to exceed 10 percent of the transient effect specifications. For measurement of slower transients (for example, temperature transient performance), a strip-chart recorder may be substituted for the oscilloscope.

13.3.5 For measurements on current stabilized power supplies, a current monitoring means is required. A suggested means is a 4-terminal resistor, chosen to drop the minimum voltage consistent with a limit of error not to exceed 10 percent of the transient effect specifications.

13.4 Set-up and Procedure — Each measurement shall be made once in each direction for a step change in the influence quantity. For example, separate measurement of the load ON and the load OFF transient shall be made. The transients associated with the application and removal of source power, start-up and turn-off decay can be measured only in the appropriate direction of their influence quantities change.

13.4.1 *Source Effect Transient* — Establish a step varying source potential. Measure the overshoot amplitude in the stabilized output quantity. Measure the time required for the stabilized output quantity to recover to within the specified transient recovery band. Care should be taken to ensure that the step modulated source voltage exhibit no overshoot or undershoot that exceed rated source limits.

13.4.2 *Load Effect Transient* — Establish a step varying load between specified limits. Care should be taken to ensure that the step-modulated load exhibits no undershoot that would go below zero or past 100 percent. Measure the overshoot amplitude in the stabilized output quantity. Measure the time required for the stabilized output quantity to recover to within the specified transient recovery band.

13.4.3 *Temperature Effect Transient* — Establish the specified step change in ambient temperature. This may be accomplished by means of a temperature controlled chamber whose ability to change temperature is such that the time required is less than one-tenth the specified temperature transient recovery time — or may be accomplished by physically removing the operating equipment from one environment to another. Measure the overshoot amplitude in the stabilized output quantity. Measure the time required for the stabilized output quantity to recover to within the specified transient recovery band (*see* Fig. 11).

13.4.4 *Initial Turn-on Transient* (*Warm-up*) — Establish a step turn-on of the source voltage. Measure the overshoot amplitude and time required for the stabilized output quantity to reach the specified warm-up band.

13.4.5 *Turn-off Decay* — Establish a step turn-off of the source voltage. Measure the overshoot amplitude and time for the stabilized output to fall below a specified value.

13.4.6 *Other Transients* — All influence quantities have (theoretically) a transient phase before the effect of their influence reaches steady-state value. To measure, establish a step change in that influence quantity with other influences at reference or specified constant value while measuring the stabilized output quantity with suitable instruments to determine its time-varying behaviour.

13.5 Alternates, Precautions and Error Analysis

13.5.1 If the transient decay exhibits an oscillatory variation about its ultimate (steady state) value, measure the time until the last excursion returns to the defined transient recovery band.

13.5.2 For load effect transients, the case of measurement may be enhanced by the use of repetitive steps. To produce a repetitive step load

for time domain observation on an oscilloscope, square-wave load modulation may be employed. This is preferred to mechanical switching for reasons of cycle stability and lack of contact bounce and/or chatter or arcing. The requirements are that the modulated load's amplifier bandwidth be capable of producing clean loading and trailing edges with rise and fall times less than one-tenth of the specified transient recovery time and a tilt of less than 5 percent in the sustained load-ON and load-OFF condition. Avoid source frequency synchronization.

13.5.3 For power supplies whose response is expected to be slow relative to the duration of switching noise associated with mechanical closure, such means may be employed to obtain the required step change in load. Such mechanical switches can be used where the magnitude of the power supply's response is at least 100 times longer than the duration of switching transients consisting of arcing and contact bounce to prevent such noise from entering the supply's feedback control loop.

14. SETTLING EFFECTS

14.1 A settling effect follows the effects, whether transient or not of a change in an influence quantity. The settling phase represents the re-establishment of system equilibrium with its environment following changed operating conditions and is usually observed when altered dissipation requires establishment of a new thermal equilibrium.

14.2 Conditions of Measurement — The requirements given in **4** shall apply.

14.2.1 *Stabilized Output Quantity* — If the power supply offers a selection of output settings, conduct the settling effects measurements at maximum rated value.

14.2.2 *Load* — If the influence quantity is not intended to vary, set load to maximum rated value.

14.2.3 *Multiple Output Power Supplies* — Conduct settling effect measurement with all outputs set and loaded to their maximum rated value.

14.3 Equipment Required

14.3.1 If the source voltage is the variable influence quantity, a means is required capable of varying the magnitude of the source voltage between the specified limits and of sufficient rating that the loading imposed by the power supply does not result in significant change in either source amplitude or distortion.

14.3.2 If load is the variable influence quantity, a means is required to load the supply, capable of switching through the range of required load.

14.3.3 A means for detecting changes in the value of the stabilized output quantity and capable of displaying this value *versus* a time base so that the settling phase can be observed. A sensitive strip-chart recorder in a differential or back-out configuration is recommended.

14.3.4 For measurements on current stabilized power supplies, a suitable current monitoring means is required. A suggested means is a 4-terminal resistor chosen to drop the minimum voltage consistent with the 10 percent limit or error.

14.4 Set-up and Procedure — The settling effect can be separated, for the purpose of measurement, from the time effect, or drift, by the method of correlation that is by showing the effect to be reversible when the influence quantity is restored to its original value.

14.4.1 *Source Settling Effect* — Establish a varying source potential from high to low and measure the amplitude of the source effect in accordance with **8**. Continue to observe the stabilized output quantity until the change induced by the altered power dissipation requirements (if any) have stabilized.

Reverse the source voltage change from low to high and measure the settling effect in the reverse direction. Calculate the average of the changes in both direction to obtain the source settling effect. This correlation of a reversible effect will tend to minimize the contributions of the time effect (drift). To further separate the settling effect from the time effect, the measurement should be repeated at least twice in each direction.

14.4.2 *Load Settling Effect* — Establish a varying load from minimum to maximum (or through other specified limits) and measure the amplitude of the load effect in accordance with **7**. Continue to observe the stabilized output quantity until the change induced by the altered power dissipation requirements, if any, have stabilized. Reverse the load from maximum to minimum and measure the settling effect in the reverse direction. Calculate the average of the changes in both directions to obtain the load settling effect. This correlation of a reversible effect will tend to minimize the contribution of the time effect (drift). To further separate the settling effect from the time effect, the measurement should be repeated at least twice in each direction.

14.4.3 *Reporting of Results* — Express the settling effect in the same units used to describe the respective individual effects and give both the amplitude of the settling effect and the time interval (starting from $5\ T\tau + 10s$) to the time where changes in the stabilized output quantity are due only to drift or PARD.

14.4.4 *Alternates, Precautions and Error Analysis* — If the settling effect is not specified by a manufacturer it shall be assumed that the amplitude of the settling effect is within the value given for the individual steady-state effect or drift specification.

15. OTHER INDIVIDUAL EFFECTS

15.1 Individual effects other than load, source and temperature effects are measured as the change of the stabilized output quantity caused by changes in a particular influence quantity, with all other influence quantities being held constant or within a range of values such that their cumulative influence on the stabilized output quantity is less than one-tenth of the specified individual effect.

While individual effects other than load, source and temperature effects are uncommon, a method of testing may be required if a manufacturer or user of power supplies specifies, for example, 'mechanical shock effect' (the change of a stabilized output quantity resulting from a specified mechanical shock applied to the power supply) or a magnetic field effect, or radiation effect, etc.

15.2 Conditions of Measurement — The requirements given in **4** shall apply.

15.2.1 *Stabilized Output Quantity* — If the power supply offers a selection of output settings, measurements should be made at several values of the stabilized output quantity to determine whether the output effect being measured depends on the output setting to a significant degree. If this is the case, the output setting which results in the greatest sensitivity to the specific influence quantity should be selected and used for the remainder of the tests. Otherwise the measurement shall be made with the stabilized output quantity at maximum value.

15.2.2 *Load* — Perform the measurement at several values of loading to determine whether the output effect being measured depends on the load to any significant degree. If so, conduct the test at the most sensitive load point; otherwise conduct the measurement at maximum loading.

15.2.3 *Multiple Output Power Supplies* — Conduct a series of measurements for each output with all other outputs set simultaneously to minimum and then to maximum value and loaded to the minimum and maximum amounts.

15.3 Equipment Required

15.3.1 A source of primary energy for the power supply, capable of being varied over the rated input range of the power supply under test.

15.3.2 A variable means for loading the power supply.

15.3.3 A means for detecting changes in the value of the stabilized output quantity, with a limit of error such that the cumulative error does not exceed 10 percent of the individual effect specification.

15.3.4 A controlled means of providing and, if necessary, varying the particular influence quantity dealt within the individual effect specification.

15.4 Set-up and Procedure

15.4.1 The details are strongly dependent upon the particular individual effect specification being tested. In any case, however, the stabilized output quantity and the individual effect influence quantity should be scanned through the rated range to determine the worst permissible combination of operating conditions (with other influence quantities under reference conditions); it is under these conditions that the individual effect is to be measured and compared with the specified value.

15.5 Alternates, Precautions and Error Analysis — If the particular effect is the result of a step change in any influence quantity, separate the transient phase and settling phase for separate measurement.

16. COMBINED EFFECTS

16.1 Combined effect is measured as the maximum change in the steady-state value of a stabilized output quantity resulting from concurrent changes in two or more of the following influence quantities:

a) Load,

b) Source voltage,

c) Source frequency, and

d) Temperature.

16.1.1 A measurement of combined effect depends upon which of the four influence quantities are named as included in the specification (load and source voltage combined effect; combined effect of load, source voltage and temperature, etc). Notice that the definition of combined effect does not include PARD, drift, settling effects or settling deviations (*see* **17**).

16.2 Conditions of Measurement — Influence quantities other than the two, three or four directly involved in combined effect shall be as specified

under reference conditions in IS : 7204 (Part II)*, Tables 1 and 2, ' Tolerance G '.

16.2.1 *Stabilized Output Quantity* — If the power supply offers a selection of output settings, conduct the measurement at maximum rated value and repeat with the stabilized output quantity set to minimum rated value. If the minimum rated value is zero, conduct the measurement at 1 percent of maximum value.

16.2.2 *Load* — If the load is chosen as one of the components of combined effect, then two load settings are used to perform the combined effect test: minimum load and maximum load.

If the load is not chosen as one of the components of combined effect, then the load should be set at maximum rated value.

16.2.3 *Source Voltage* — If the source voltage is chosen as one of the components of the combined effect then three source voltages are used to perform the combined effect test. One is with the source voltage set to the lowest specified value, and the second is with the source voltage set to the nominal and third is set to the maximum rated value.

16.2.3.1 If the source voltage is not chosen as one of the components of combined effect, then the source voltage should be set at its reference value.

16.2.4 *Source Frequency* — If the source frequency is chosen as one of the components of combined effect, then two source frequencies are used to perform the combined effect test: the minimum and maximum rated nominal source frequencies.

If source frequency is not chosen as one of the components of combined effect, then a source should be employed which has the nominal frequency value specified, or any of the nominal values which may lie within the rated frequency band.

16.2.5 *Temperature* — If temperature is chosen as one of the components of combined effect, then two temperatures are used to perform the combined effect measurement; the minimum and maximum rated temperatures.

If temperature is not chosen as one of the components of combined effect, then the ambient temperature to be maintained during the measurement is the specified reference value.

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*Specification for stabilized power supplies dc output : Part II Power supplies, their rating and performance.

16.2.6 *Multiple Output Power Supplies* — Conduct a series of measurements for each output with all other outputs set simultaneously to minimum and then to maximum value and loaded to minimum and maximum amounts.

16.3 Equipment Required

16.3.1 A source of primary energy for the power supply, capable of being varied over the rated input range of the power supply.

16.3.2 A variable means for loading the power supply.

16.3.3 A means for detecting changes in the value of the stabilized output quantity.

16.3.4 A controlled means of providing and, if necessary, varying the particular influence quantity dealt within the individual effect specification.

16.4 Set-up and Procedure — Establish a list of all measurement permutations in two groups, one for each output setting. For each group, a set of measurements is made. Within each group the minimum and maximum values are selected from the set of measurements, and their difference is computed. The larger of these two difference is the measured value of the combined effect.

16.5 Alternates, Precautions and Error Analysis

16.5.1 For each of the influence quantities which are named as components of the combined effect specification, refer to the 'Alternates, precautions and error analysis' section of the test procedure for that individual effect specification for applicable comments. For example, if load effects are named as one of the components of combined effects, refer to **7.7** for applicable comments, etc.

16.5.2 Although it is not generally true that combined effect equals the sum of its component individual effects, practical considerations in some cases will dictate the use of an alternate procedure involving only $2n$ measurements, a set of n measurements at each of the two output values (minimum and maximum rated), where n is the number of individual effect components contained in the combined effect specification. In such cases the magnitudes of each of the set of n measurements are added, and the larger sum is selected as the measured combined effect. Since it is more common for this alternate method to yield a result which is similar or larger (rather than smaller) than the preferred measurement method, this alternate method yields in most cases a result which can be considered a conservative or pessimistic appraisal of the power supply's performance capability.

17. TOTAL EFFECT

17.1 Total effect is the maximum change in the steady-state value of the stabilized output quantity resulting from concurrent changes in all influence quantities within their rated ranges.

17.2 Conditions of Measurement — The requirements given in **4** shall apply.

17.3 Equipment Required — Refer to individual measurement procedures.

17.4 Set-up and Procedure — Because of the larger number of possible influence quantities and output effects, a measurement technique which follows strictly from the definition would involve a large number of combinations of measurement conditions with a large number of output quantities to be measured at each condition. To reduce this task (and obtain a measurement result which is normally accurate and more likely to err on the conservative side), the following procedure is recommended.

17.4.1 Measure the combined effect resulting from the influence of load, source voltage, source frequency, and temperature changes, following the procedure of **16**.

17.4.2 Measure PARD according to **9.**

17.4.3 Measure drift according to **10.**

17.4.4 Measure settling effects according to **14.**

17.4.5 Measure the individual effect associated with any other influence quantities which are specified according to **15.**

17.4.6 Add the magnitudes of the results of the measurements for the combined effect, PARD, drift, settling effects and other individual effects. The result is the computed value for total effect.

18. MEASUREMENT OF QUANTITIES RELATED TO THE SOURCE

18.1 Quantities related to the source are:

a) inrush current,

b) rated source current,

c) efficiency,

d) power factor, displacement factor, and

e) source current distortion.

18.1.1 All above quantities are measured under steady-state operating conditions with the exception of the inrush current which is measured during the start-up time.

18.2 Conditions of Measurement — The requirements given in **4** shall apply.

18.2.1 *Stabilized Output Quantity* — If the power supply offers a selection output settings, conduct the measurement at maximum rated value. If the minimum value is zero, conduct the measurement at 50 percent of maximum value.

18.2.2 *Load* — At least two load settings are used to perform these tests : maximum rated load and 50 percent of maximum rated load.

18.2.3 *Multiple Output Power Supplies* — Conduct a series of measurements with all outputs set simultaneously to the 100 percent and (if applicable) 50 percent point and loaded simultaneously to full and to 50 percent of maximum rated load.

18.3 Equipment Required

18.3.1 A source of primary energy.

18.3.2 A means of loading the power supply, capable of dissipating the output energy and able to be changed to provide the required values of load.

18.3.3 A means of measuring the steady-state rms (for ac) or mean (for dc) value of the source voltage and current, the waveform distortion and the active source power.

18.3.4 A means to measure the instantaneous peak value of the source inrush current, its duration and wave shape. The total impedance of the instrumentation when added to the source's own impedance shall cause, during the peak inrush current at the power supply terminals, a maximum instantaneous source voltage drop at the power supply terminals of less than 10 percent of the rated value at no load. The resolution, stability and accuracy of all the instrumentation shall be sufficient to ensure a limit of error not to exceed 10 percent of the specification tolerance.

18.3.5 A means for measuring the output power with sufficient resolution, stability and accuracy to ensure a limit of error not to exceed 10 percent of the specification tolerance.

18.4 Set-up and Procedure

18.4.1 Connect source, load and instrumentation to the power supply as given in Fig. 12.

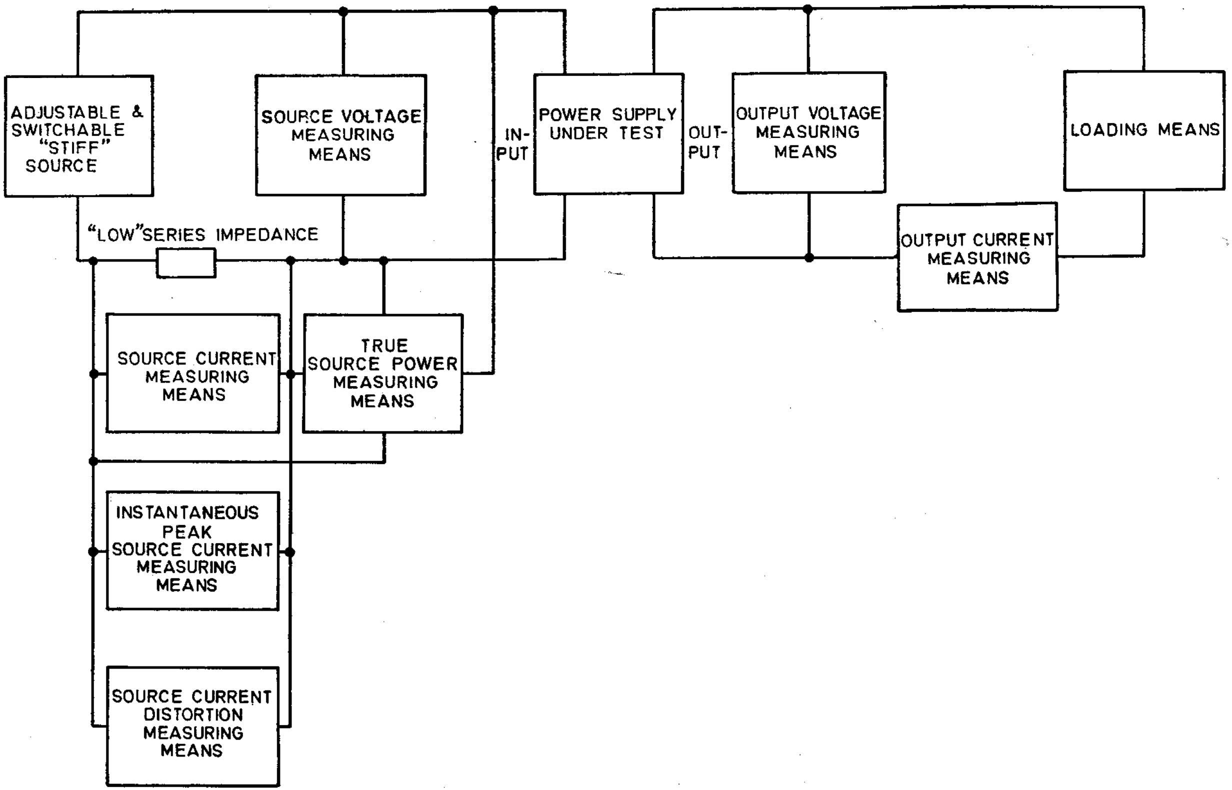

Fig. 12 Set-up for Measurement of Quantities Related to the Source

18.4.2 Determine rated source current, efficiency, power factor and source current distortion by measuring the source voltage, source current, output voltage, output current, source current distortion and active source power (the latter two for ac sources only) under the steady-state source and load conditions described in **18.2**. From the measured quantities, calculate efficiency and the power factor as follows:

$$\text{Efficiency (in percent)} = \frac{\text{Output voltage} \times \text{output current}}{\text{Active source power}} \times 100$$

$$\text{Power factor} = \frac{\text{Active source power}}{\text{Source voltage} \times \text{source current}}$$

For dc sources, the active source power is the product of the source voltage and source current (power factor is unity).

18.4.3 Measure the inrush current by applying the source voltage to the power supply through an instantaneous switch and measuring the maximum instantaneous peak value of the source current pulse(s), its time duration and wave shape. The rms value is calculated from these data. For ac sources, the maximum peak may be a function of the source voltage phase angle at turn-ON. To obtain the true maximum peak value, see the procedures under **18.5.3**.

18.5 Alternates, Precautions and Error Analysis

18.5.1 To ensure a proper measurement of the active source power for an ac source, the instrument used should measure power under the presence of the (measured) source current distortion and phase angle, to the accuracy requirements of **18.3.3**.

18.5.2 Power supplies that have substantially varying efficiency and/or power factor as a function of load, may require curves to describe this function. In such cases, the load will have to be set to a number of separate values such that the measured quantities will allow the plotting of curve(s) to the required accuracy.

18.5.3 Several different methods can be used to measure the ac inrush current. A few of these are listed below:

a) *The statistical method* — According to the rules of binomical distribution, the probability (P_k) of measuring at least once any one alternative (P) amongst all possible results in a number of dependent trials (n), is equal to:

$$P_k = 1 - (1 - P)^n$$

This formula is based on one independent variable, that is, the change of only one quantity will basically determine the maximum peak inrush current, all other quantities either do not vary or their change will have no substantial influence. In such a case, a 90 percent chance of success in measuring the maximum peak inrush current to within a 10 percent accuracy demands that at least 22 random turn-ON tests be made, because

$$1 - (1 - 0{\cdot}1)^{22} = 0{\cdot}9$$

Should the circuit be such that two or more variable quantities have influence over the maximum peak inrush current, the number of random turn-ON tests have to be at least the number of variables multiplied by 22; for example, if the variables are the source voltage and the residual induction of a transformer, the minimum number of turn-ONs is 44.

b) *The synchronous switch method* — The source is turned on by a controlled switch at a number of predetermined phase angles in order to search out the maximum. The switch should close firmly in one-tenth or less of the inrush current rise time. The impedance represented by the switch should be added to the series impedance of the instrumentation and source. The total impedance should still meet **18.3.4**.

19. CAPACITANCE TO SOURCE TERMINALS

19.1 Capacitance to source terminals is the capacitance measured between the specified source terminals and output terminals.

19.2 Conditions of Measurement — The power supply shall be deactivated, with no outside connections to its source, control input and output terminals, except for connections to the test apparatus.

19.3 Equipment Required — This includes a signal generator, an oscilloscope and a monitoring resistor R_M (*see* Fig. 13).

19.4 Set-up and Procedure

19.4.1 The output terminals are shorted together and connected to one side of the monitoring apparatus, the other side being connected to ground. The source terminals are shorted and connected to one side of the signal source, the other side of which is connected to ground. Control input terminals are shorted to the output terminals; if in normal operation they are conductively connected to the output. They are shorted to ground if they are internally isolated from the output terminals and are normally connected to a local or remote ground. They would be left unconnected for test purposes only if in normal operation they are not

conductively connected to either one of the output terminals or the power supply ground, frame, or chassis.

19.4.2 The power supply is connected to the test instruments as shown in Fig. 13. A signal generator voltage is injected between chassis ground and the two shorted input terminals. The dc output terminals are shorted together and a resistor R_M is inserted between them and chassis ground. There may exist some stray capacitance in shunt with R_M, and the measurement method may have to take the effect of C_G into account, depending upon the frequency of measurement and the values of the constants involved. Use a 1 kΩ resistor for R_M. An oscilloscope should be used to monitor the voltage across R_M, in order that pick up and effects, not related to the excitation from the signal generator, can be eliminated or ignored. Alternatively, a voltmeter turned to the same frequency as the signal generator may be used.

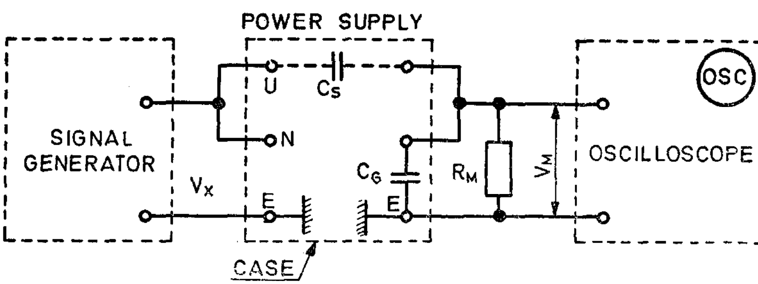

FIG. 13 MEASURING CAPACITANCE TO SOURCE TERMINALS

19.4.3 Using the equivalent circuit of Fig. 13, compute the value for C_S, knowing the values of R_M, C_G, V_X and V_M. It is useful to adjust the input frequency so as to simplify the procedure:

if (a) $R_M \ll X_{C_G}$; and

(b) $R_M \ll X_{C_G}$,

$$\text{Then, } C_S = \frac{V_M}{V_X} \times \frac{1}{2\pi f R_M}$$

19.4.4 Check conditions (a) by verifying that in the interval of measurement V_M is inversely proportional to f, the frequency of the applied excitation, and that V_M is proportional to R_M. Condition (b) will be met if condition (a) has first been satisfied and $V_X \gg V_M$. In order

to satisfy these conditions and use the simple relationship for C_S given above, it may be necessary to adjust either R_M or f until a suitable combination is found.

19.4.5 As a final check that stray signals are not influencing the measurement, it should be verified that V_M goes to zero when V_X is reduced to zero.

20. CAPACITANCE TO FRAME

20.1 Capacitance to frame is the capacitance measurable between a specified terminal (or set of terminals) and a common point such as frame, guard or ground. The most commonly encountered capacitance to frame is the capacitance from output to frame.

20.2 Conditions of Measurement — The power supply shall be deactivated, with no outside connections to its source, control input and output terminals, except for connections to the test apparatus.

20.3 Equipment Required — These include an impedance bridge, a capacitance meter or a signal generator, series resistor and sufficient metering to facilitate ac voltage measurement across the resistor and the power supply capacitance being measured.

20.4 Set-up and Procedure

20.4.1 In general, the capacitance to frame is specified with respect to a set of terminals; if there is more than one member of this set, they should shorted together for test purposes. Any unspecified terminals should be evaluated with respect to their normal conductive connections and, accordingly, should be shorted to frame (ground), or shorted to the set of specified terminals, or left unconnected.

20.4.2 For measuring the capacitance from output to frame, the output terminals are shorted together and connected to one side of the test apparatus while the source terminals and ground terminal are shorted to frame or chassis and then to the other side of the test apparatus. Control input terminals are shorted to the output terminals if in normal operation they are conductively connected to the output. They are shorted to ground if they are internally isolated from the output terminals and are normally connected to a local or remote ground. They would be left unconnected for test purposes only if, in normal operation, they are not conductively connected to either one of the output terminals or the power supply ground, frame or chassis.

20.4.3 Perform measurements in accordance with procedures suitable to the particular instruments included in the test apparatus.

20.4.4 An impedance bridge or capacitance meter will permit a satisfactory measurement, if the capacitance is specified with the power supply de-energized. If it is desired to measure this capacitance with the power supply activated, an impedance bridge or capacitance meter may not be suitable, either because of possible damage to the measuring instrument, the power supply dc output potential (which might be eliminated with a blocking capacitor), or because of the difficulty of obtaining a precise measurement result in the presence of noise on the power supply output or noise arising from ground loop or stray paths. Thus, measurement of capacitance to frame for an activated power supply is most easily accomplished with a signal generator, a series resistor and blocking capacitor (to protect the signal generator from the power supply is dc output voltage) and an oscilloscope. The oscilloscope is first used to monitor the ac voltage across the resistor and then across the designated power supply terminal(s) and frame. The ratio of the amplitude of these two measurements and the known value of the series resistor enables the calculation of the capacitive reactance and then the capacitance to frame. The oscilloscope display will reveal any measurement error attributable to noise or pick-up. A sinusoidal waveform shall appear across both the series resistor and the terminals being measured.

21. COMMON-MODE MEASUREMENT

21.1 The common-mode (leakage) current is that current which flows between the power supply's floating output terminals and a common point such as frame, chassis, ground or shield.

21.2 Conditions of Measurement — The requirements given in **4** shall apply.

21.2.1 *Stabilized Output Quantity* — If the power supply offers a selection of output settings, conduct the common-mode current measurement at maximum rated value.

21.2.2 *Load* — Perform the common-mode current measurement with the power supply unloaded.

21.3 Equipment Required

21.3.1 A minimum of two suitably non-reactive measuring resistors.

21.3.2 A means for measuring the voltage dropped across the measuring resistors which input impedance is 2-orders of magnitude greater than the selected value for the measuring resistor and whose frequency characteristics is suitable for the measurement of common-mode signals at source frequency and to the fourth harmonic.

NOTE — If measurement of high frequency common-mode current is desired and bandwidth is specified, then the measuring instrument and measuring resistor should be suitably rated.

21.4 Set-up and Procedure

21.4.1 Connect the measuring resistors successively between each output terminal and frame, or guard, or ground. Measure the voltage across the measuring resistor to determine the current flowing. Repeat with the second measuring resistor.

21.4.2 Choose the values of the measuring resistors to that the ratio of voltage to resistance (current) is constant for the two values of resistance.

21.5 Alternates, Precautions and Error Analysis — Internal connections from any output terminals to frame, guard, or ground shall be disconnected for the purpose of this measurement whether they be resistive, capacitive or otherwise.

22. BOUNDARY CONDITION MEASUREMENTS

22.1 Boundary condition measurements encompass the performance of protective mechanism which limit the maximum value of the unstabilized output quantity. For a voltage supply, the current is the unstabilized quantity to be bounded; for the current supply, voltage is the unstabilized quantity to be bounded. The actual conduct of each test will be dependent on the type of bounding mechanism employed in the power supply being tested. In general, the tests shall be designed to yield the following data:

a) Limit threshold, the value of the unstabilized output quantity which is detected by its effect on the stabilized output quantity;

b) *Maximum Limited Value* — The maximum value of the unstabilized output quantity for any value of load which can persist for an extended duration. (Defined as one second for the purposes of this measurement).

c) The peak value of the unstabilized output quantity for any value of load. The existence of a peak implies a transient condition for which duration shall also be determined.

b) The value of the unstabilized output quantity for the extremity of load (short-circuit current or open-circuit voltage as the case may be).

22.1.1 Bounding mechanisms may be of several general types with many individual varieties within each type as indicated below:

a) ' One-shot ' types which require a manual reset or replacement;

b) ' Automatic ' types which restore the stabilized output quantity following a reduction in the unstabilized output quantity below the limit threshold.

c) Combinations of the automatic and one-shot types for protection redundancy.

22.1.1.1 Examples of one-shot mechanisms are:

a) Fuses,
b) Circuit breakers of the ' trip ' type, and
c) Crowbars.

22.1.1.2 Examples of ' automatic ' mechanisms are:

a) Circuits which reduce the stabilized output quantity in order to limit the previously unstabilized output quantity;
b) Circuits which limit the previously unstabilized output quantity in such a way as to be considered a stabilizer of that quantity for a range of load values, known as an automatic crossover circuit;
c) Circuits which reduce both output quantities in proportion to each other, known as foldback or re-entrant limiters; and
d) Sampling circuits, which having cut off all or part of the output, periodically re-apply power to determine the continued present or not of an overload.

22.2 Threshold Measurement

22.2.1 *For Voltage-Stabilized Power Supplies* — The current limit threshold is measured as the value of the output current for which limiting action can be detected by the departure of the stabilized voltage from its specified load-effect band.

22.2.2 *For Current-Stabilized Power Supplies* — The current limit threshold is measured as the value of the output voltage for which limiting action can be detected by the departure of the stabilized current from its specified load-effect band.

22.3 Conditions of Measurement — The requirements given in **4** shall apply.

22.3.1 Threshold measurements shall be made with the source voltage amplitude set to the lowest rated value and repeated with the source voltage amplitude set to the highest rated value.

22.3.2 *Stabilized Output Quantity* — If the power supply offers a selection of output settings, conduct the threshold measurement at maximum rated value and repeat with the stabilized output quantity set to minimum rated value. If the minimum rated value is zero, conduct the test to 10 percent of maximum value.

22.3.3 *Load* — The variable influence quantity for this test is the load which is to be varied from its minimum value to the threshold value.

22.3.4 *Multiple Output Power Supplies* — Conduct a series of threshold measurements for each output with all other outputs set simultaneously to minimum and then to maximum value and loaded to the minimum and maximum amount.

22.4 Equipment Required

22.4.1 A source of primary energy for the power supply capable of of varying the magnitude of the source voltage between the specified limits and of sufficient rating so that the loading imposed by the power supply does not result in significant change in either source amplitude or distortion.

22.4.2 A means for loading the power supply capable of dissipating the output energy and able to be changed to provide the required values of load.

22.4.3 A means for detecting changes in the value of the stabilized output quantity so that the limit threshold can be determined.

22.4.4 A means for measuring the output voltage or current with sufficient resolution, stability and accuracy to insure a limit of error not to exceed 10 percent of the threshold tolerance specification.

22.5 Set-up and Procedure

22.5.1 *For Voltage-Stabilized Power Supplies*

22.5.1.1 Connect load and output monitoring equipment to the power supply so that the current drawn by the load causes negligible error in the measured value.

22.5.1.2 Perform the limit threshold measurement by gradually varying the load current from its minimum value to and then past its rated maximum value. Record the value of the current at which limiting action is first detected as a reduction in the stabilized output voltage below the load-effect band, the total-effect band or tolerance band, as applicable.

22.5.1.3 If the current limiter is adjustable, repeat this measurement to determine the minimum and maximum value.

22.5.1.4 For each combination of source voltage and output setting, measure the current limit threshold and the range of its setting. These observations constitute the set of current limit threshold measurements.

22.5.2 *For Current-Stabilized Power Supplies*

22.5.2.1 Connect the current monitoring means so that its terminal voltage is exclusively proportional to the output current.

22.5.2.2 Measure the voltage limit threshold by gradually varying the load voltage from its minimum value to and then past its rated maximum value. Record the value of the voltage at which limiting action is first detected as a reduction in the stabilized output current below the load-effect band, the total-effect band or tolerance band, as applicable.

22.5.2.3 If the voltage limiter is adjustable, repeat this measurement to determine the minimum and maximum value.

22.5.2.4 For each combination of source voltage and output setting, measure the voltage limit threshold and the range of its setting. These observations constitute the set of voltage limit threshold measurements.

22.6 Measurement of Maximum Limited Values — After the threshold values for voltage and current are determined as described in **22.5**, continue to increase the loading (toward shortcircuit for the voltage stabilized power supplies and towards open circuit for the current-stabilized power supplies).

Measure the maximum values of the load current and load voltage respectively which exist for the minimum of one second. These are maximum limited values.

22.7 Measurement of the Value of the Bounded Output Quantity for the Extremity of Load — Increase the loading to the respective extremities (respectively short-circuit and open-circuit). Then measure the values of the bounded output quantity. For many types of voltage limited/current limited power supplies this value will be identical to the maximum limited value; for power supplies protected by one-shot devices or re-entrant limiters; the value may be different or zero.

22.8 Measurement of the Peak Value of the Bounded Output Quantity

22.8.1 For this measurement, the following additional equipment will be required:

a) Means for step switching the load from maximum rated load to its extremity (open-circuit or short-circuit); and

b) Means for observing the time behaviour of the bounded output quantity. An oscilloscope is the recommended instrument.

22.8.2 *Procedure* — Step switch the load from its maximum rated value to the respective extremity while observing the bounded output quantity.

Record the amplitude of the transient and the time required to decay to the steady-state value. (This may be the time required to activate a one-shot protector such as a circuit breaker or fuse.)

23. SOUND LEVEL MEASUREMENT

23.1 Audible sound level in the arithmetic average of several readings made with a sound level measuring instrument defined in IS : 6872-1972* set to response curve A. The sound level is a sound pressure level given in decibels above a reference pressure of 2×10^{-5} Pa, artificially weighted to approximate the frequency response of the human ear.

23.2 Conditions of Measurement — The requirements given in **4** shall apply.

23.2.1 *Stabilized Output Quantity* — Maximum rated output.

23.2.1.1 Measurements are to be made at two values of load — zero and maximum rated value.

23.2.1.2 *Multiple output power supplies* — Conduct the sound level measurement with all outputs simultaneously loaded and unloaded.

23.3 Equipment Required

23.3.1 A room with an ambient sound level of at least 4 dB and preferably 10 dB or more lower than the sound level of the power supply and ambiency combined. There shall be no acoustically reflecting surface, other than the floor or ground within 3 metres of the power supply. The dimensions of the room may be smaller if walls and ceiling are properly acoustically treated. A pad of foam rubber 2·5 cm thick shall be placed over any surface upon which the power supply is placed.

23.3.2 A sound level measuring instrument in accordance with IS : 6872-1972*.

23.4 Set-up and Procedure

23.4.1 Energize power supply at reference voltage and frequency with no load connected. Any forced cooling means shall be operating.

23.4.2 Make 5 sound level measurements at a distance of 30 cm from the surface of the power supply such that 4 measurements are taken at intervals of approximately 90° around the power supply in horizontal plane bisecting it and one measurement is taken above the power supply. Maintain specified distance and vary position of microphone to obtain highest sound level reading.

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*Specification for radio interference measuring apparatus for the frequency range 0·15 MHz to 1 000 MHz.

23.4.3 Repeat with maximum load connected.

23.4.4 Determine ambient sound level, with power supply sound level, with power supply de-energized, immediately before and after measurements listed above. The assumed ambient level is the average of these two readings.

23.5 Calculation of Sound Level

23.5.1 *Correction of Measured Values* — If the ambient level is between 4 dB and 10 dB below any of the measured values, as apply, corrections given below:

Difference in Decibels Between the Sound Level of Power Supply and Ambiency Combined and Sound Level of Ambiency	*Corrections in Decibels to be Applied to Sound Level of Power Supply and Ambiency Level Combined, to Obtain Sound Level of Power Supply*
4	− 2·2
5	− 1·7
6	− 1·3
7	− 1·0
8	− 0·8
9	− 0·6
10	− 0·4
Over 10	− 0·0

23.5.2 The sound level of the power supply is the arithmetic average of 5 corrected measurements.

24. CONTROL EFFECTS

24.1 Measurement of the control effects include but are not limited to:

a) setting range,
b) control range,
c) control resolution,
d) control rate,
e) control time constant,
f) control coefficient, and
g) control deviation.

24.2 Conditions of Measurement — The requirements given in **4** shall apply except for load.

24.2.1 For measurement of the following, conduct the measurements, with the power supply not loaded:

a) setting range,
b) control resolution,
c) control coefficient, and
d) control deviation.

24.2.2 For measurement of control ratio, control time constant perform two sets of measurements, one with the power supply fully loaded, the second with the power supply not loaded.

24.2.3 To make the measurements on control range, the following combinations of influence quantities shall be arranged:

a) *Source amplitude* — Set to minimum and then to maximum value.
b) *Load* — Set to minimum and to maximum value.
c) *Temperature* — Set to minimum and to maximum value.

24.3 Equipment Required

24.3.1 A means for measuring the stabilized output quantity whose calibration may be checked against an independent standard with an accuracy compatible with the tolerances require for the measurements.

24.3.2 A means for displaying the stabilized output quantity against a calibrated time base.

24.3.3 A means for exercising output control that is furnished or recommended by the power supply's manufacture.

24.4 Set-up and Procedure

24.4.1 *Setting Range* — Adjust the selected control means to vary the power supply's stabilized output quantity. Measure the extreme range over which control is exercised.

24.4.2 *Control Range* — For selected output settings near the minimum and maximum extreme permute the influence quantities of load, source amplitude and temperature while measuring PARD, and the output effects to determine the maximum range of output settings for which the equipment meets all applicable specifications.

24.4.3 *Control Resolution* — By sensitive measuring means, determine the smallest reproducible increment in the stabilized output quantity that the selected control can provide.

24.4.4 *Control Rate* — By measuring means which observe the stabilized output quantity against a calibrated time base, determine the maximum

rate at which the stabilized output can be increased and can be decreased without having the output depart from the control deviation band. That is, measure the maximum rate of change for which the output waveshape reproduces the control function to within the tolerance allowed by the control deviation band.

24.4.5 *Control Time Constant* — By measuring means which observe the stabilizing output quantity against a calibrated time base, determine the maximum exponential rate at which the stabilized output quantity responds to a step change in the control quantity.

NOTE — Both control rate and control time constant measurements are to be performed with the power supply fully loaded in both an increasing output and a decreasing output direction, and then repeated with the power supply unloaded to form a set of four measurements for each.

24.4.6 *Control Coefficient* — By this measurement determine the amount of change in the control quantity necessary to effectuate a specified change in the stabilized output quantity.

To determine the amount of nonlinearity, make a series of such coefficient measurement at 10, 30, 50, 70 and 90 percent outputs. Repeat the measurement for the increasing output and decreasing output direction.

24.4.7 *Control Deviation* — For each measuring point at which the control coefficient is determined, 10, 30, 50, 70 and 90 percent, record the difference between the actual value of the stabilized output quantity and the predicted value obtained by multiplying the control coefficient by the control quantity.

By successive measurements at (or near) zero output and 10 percent output, the control deviation can be categorized as to offset (zero) error, slope (calibration) error, and nonlinearity.

25. ISOLATION VOLTAGE

25.1 The test voltage and method of test shall be as agreed between the manufacturer and the user.

26. INSULATION RESISTANCE TEST

26.1 The insulation resistance shall be measured with the apparatus not connected to its supply source. A dc voltage of 100 V is applied to it and the measurement is carried out 1 minute after application:

a) for output circuit(s) internally connected to the input, between:
   1) the frame, and
   2) all output terminals short-circuited and connected together.

b) for output circuit(s) insulated from the input between:

1) the frame connected to one input terminal, and

2) all output terminals short-circuited and connected together.

NOTE 1 — The insulation between different output circuits may be considered.

NOTE 2 — The measurement refers to the functional performance of the apparatus. It may not be adequate for safety purposes.

27. INSULATION TEST VOLTAGE

27.1 Unless otherwise agreed, the rms values of the test voltage shall be 2 000 V or 2 U + 1 000 V, where U is the rated voltage. The test voltage shall be applied gradually, starting at 50 percent and increasing to full value in not less than 10 seconds between the metallic enclosures and terminals (input and output).

27.2 The test shall be conducted at room temperature.

NOTE — Care shall be taken to disconnect the electronic control circuits during the test as some of the electronic components may fail during the voltage test.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/
Frequency	hertz	Hz	1 Hz = 1 c/s
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/
Pressure, stress	pascal	Pa	1 Pa = 1 N/m

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